Prediction and Optimization of Truss Performance for Lightweight, Intelligent Packaging and Deployable Structures

Completed Technology Project (2016 - 2020)

Project Introduction

Recent advances in fabrication techniques have enabled the creation of large metallic, polymeric, or ceramic truss lattices with the smallest beam dimension on the micron- and nanometer-scales, which form a new class of cellular meta-materials with tunable macroscopic properties. These lattice materials, which can bridge many length scales, offer desirable mechanical properties such as high stiffness and strength while having extremely low density. However, by manipulating the arrangement and architecture of trusses, fabricable lattices have been shown to exhibit many other novel properties, including large nonlinear recoverability and large energy absorption due to the wide mechanical hysteresis produced by the buckling of truss members. Because of the above properties, microlattices are excellent candidates for applications ranging from impact absorption in sandwich cores to deployable space structures. Fabrication and testing of these multiscale structures are available, but the prediction of the response of complex trusses to large inelastic deformation, large rotations, inelasticity and failure requires accurate computational tools that severely restrict the number of truss members that can be modeled on realistic computing resources. Since these lattices span many length scales, thousands to millions of truss members need to be simulated in order to resolve the behavior of the structures at the largest and smallest scales. The inability to predict the response of these structures through simulation leads to a trial-and-error design cycle, which is extremely inefficient. The proposed research will fill the void in the design process by creating a computational tool capable of predicting the complex nonlinear response of truss lattices containing extremely large numbers of beams and nodes. The technique will borrow concepts from the traditional quasicontinuum (QC) method, which is a powerful multiscale modeling method originally designed to drastically lower the computational cost of simulating atomistic lattices through coarse graining. My research advisor, Professor Dennis Kochmann, already has a massively parallel QC code, which will be extended to TrussQC, a high-performance computational toolbox for the simulation of large trusses. We will focus on metallic and polymeric trusses with micron-sized or larger truss members whose response is sufficiently well described by a continuum representation (i.e., well above nano-scale size effects). This has been shown to even apply for nanolattices when loaded in the linear elastic regime. Although the proposed techniques are equally applicable to all scales (as long as a model for the response of individual beams and nodes is available), we focus on micro-to-macrolattices due to the scalability of current manufacturing methods. The proposed research will develop and implement computational tools to understand the effect of microstructural nonlinearities and predict and optimize the large-deformation, dynamic, inelastic macroscopic performance of complex cellular truss structures in situations relevant to NASA, e.g. impact energy absorption in sandwich cores or the deployment of lightweight foldable structures. Lastly, non-destructive sensing to assess the mechanical integrity of these periodic structures will be investigated by computationally comparing the wave attenuation profiles of

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damaged and undamaged lattices.

Anticipated Benefits

The proposed research will develop and implement computational tools to understand the effect of microstructural nonlinearities and predict and optimize the large-deformation, dynamic, inelastic macroscopic performance of complex cellular truss structures in situations relevant to NASA, e.g. impact energy absorption in sandwich cores or the deployment of lightweight foldable structures.

Primary U.S. Work Locations and Key Partners
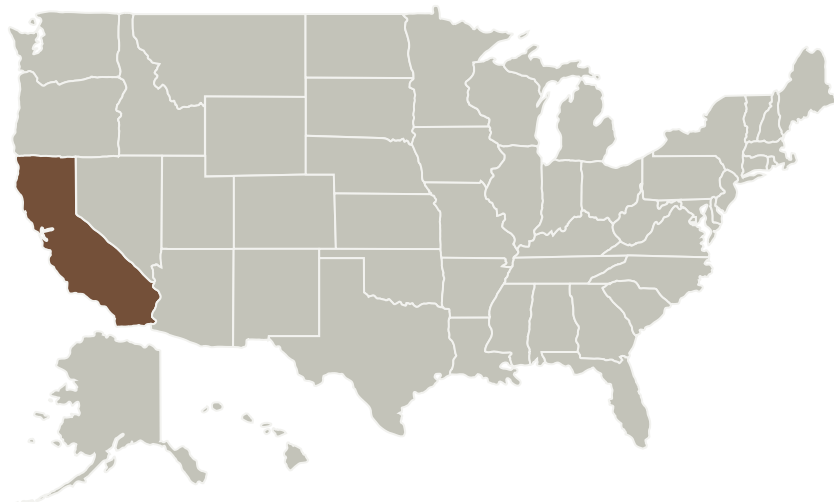
Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Lead Organization	Academia	Pasadena, California

Primary U.S. Work Locations
California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

California Institute of Technology (CalTech)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Dennis Kochmann

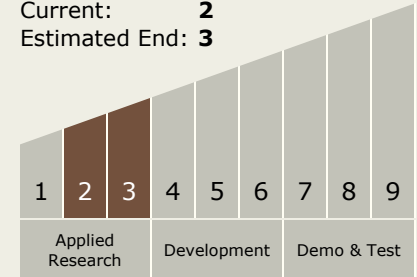**Co-Investigator:**

Gregory Phlipot

TechPort

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For more information and an accessible alternative, please visit:
https://techport.nasa.gov/view/88613

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Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.1 Materials
    └ TX12.1.1 Lightweight Structural Materials

Target Destination

Foundational Knowledge